

SWATCH TEST RESULTS OF PHASE 2 COMMERCIAL
CHEMICAL PROTECTIVE GLOVES TO CHALLENGE
BY CHEMICAL WARFARE AGENTS:
SUMMARY REPORT

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Research and Technology Directorate

January 2001

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13. ABSTRACT (Maximum 200 words) Swatches for four commercially available chemical protective gloves were challenged with liquid droplets of Sarin (GB) and mustard (HD) using modifications of the static diffusion procedure described in TOP 8-2-501. The cumulative mass of each agent that permeated each swatch was determined over time and the results for all swatches were used to determine an average cumulative mass for each glove. From these data, a breakthrough time was calculated for each glove/agent combination for the purposes of comparison.				
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EXECUTIVE SUMMARY

As part of the Domestic Preparedness Program, four commercially available glove designs were tested to assess their capability to protect in a chemical warfare (CW) agent environment. Swatches of material from each glove design were tested for resistance to permeation for Sarin (GB) and mustard (HD). From these data, the authors calculated the estimated time it would take to permeate the glove with sufficient agent to cause physiological effects in a person wearing the glove. The tests are described and the calculated breakthrough times are presented.

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PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Soldier and Biological Chemical Command (SBCCOM) Program Director for Domestic Preparedness.

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The panel reviewed and commented on the test procedures, instrumentation, data analysis and presentation. Their guidance was a valuable element in the development of clear and adequate descriptions of the concepts and procedures used in these tests.

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TEST RESULTS OF PHASE 2 COMMERCIAL CHEMICAL PROTECTIVE GLOVES TO CHALLENGE BY CHEMICAL WARFARE AGENTS: SUMMARY REPORT

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing their preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance federal, state and local emergency and hazardous materials (HAZMAT) response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, those emergency and HAZMAT personnel responding to an incident will use personal protective equipment (PPE) to protect them from exposure to chemical agents or biological agents. The specific PPE that would be used by these federal, state and local emergency and HAZMAT personnel would depend upon the situation encountered and the PPE held in inventory. In some cases, chemical protective gloves may be required to enter a contaminated or potentially contaminated area.

2. OBJECTIVES

This study evaluated some commercially available and commonly used chemical protective gloves to assess how well they resist vapor permeation from liquid contamination¹ by chemical agents Sarin (GB) and mustard (HD). This information is intended for federal, state and local emergency and HAZMAT personnel as an aid in their evaluation (and possible modification) of current work rules regarding specific chemical protective gloves currently in

¹ Throughout this report the term permeation is used even though for some of the tests the precise mechanism of agent transfer is not determined and penetration is possibly involved also.

inventory, and as an aid in future procurement of appropriate chemical protective gloves. This is especially important if these personnel choose to include military chemical and biological agent protection as a criterion. The information supplements data and information provided by the glove manufacturers. The gloves were tested in new, as-received condition. The effects of aging, temperature extremes, laundering, and other factors were beyond the intended scope of this test program. These tests were conducted to assess percutaneous (i.e. skin) protection only.

3. TESTING AND DATA ANALYSIS

3.1 Testing Overview

The chemical protective gloves that were tested in this test program are listed in Appendix A. Testing gloves included a permeation test of material swatches to measure the permeation of both GB and HD through the swatches.

3.2 Liquid Challenge/Vapor Permeation Testing (Agent Swatch Testing)

3.2.1 Liquid Challenge/Vapor Permeation Testing Procedures

This testing was conducted to measure the vapor permeation of chemical agents GB and HD through glove swatches over a 24-hr period. The test was intended to assess how well the glove materials resist agent vapor permeation. The amount of agent applied and duration of exposure did not represent any particular threat that responders may encounter, but served as a common point of reference for all test results.

The test methodology was taken from TOP 8-2-501² and is described in Appendix B. Twelve swatches were cut from three pairs of each glove design to be tested. Six of the

² Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT. 3 March 1997, UNCLASSIFIED Report (AD A322329).

twelve swatches were cut from the palm and six were cut from the cuff. Swatches were taken from approximately the same locations for all gloves; from the center of the palm and from the cuff area near the end of the glove. Three of the palm swatches and three of the cuff swatches were allocated to GB testing and the remainder were allocated to HD testing. Swatches were taken from silicone (M45 military mask formulation) slabs for use as a source of HD or GB vapor, after contamination.

Swatch thicknesses were measured with an Ames Dial Comparator, Model 2 (B. C. Ames Co., Waltham, MA). Five readings per swatch were taken and averaged to yield an average thickness for each swatch. The individual thickness readings for all swatches were then used to calculate the average swatch thickness in mils.

The permeation apparatus contained seven test cells. For each test, swatches from one glove design were placed in six of the cells, palm and cuff swatches were placed in alternating cells, and a silicone swatch was placed in the seventh cell. Swatches were only taken from the palm (not the back) and the cuff. In the analysis, the palm swatch was assumed to represent the palm, fingers and back of the hand and the cuff was assumed to represent the remainder of the glove that covers the wrist and forearm area.

Laboratory personnel applied a predetermined liquid agent challenge of 10 g/m^2 to the top surface of each swatch. Agent droplets were applied to the surface of the first swatch at time zero. Agent was then applied to the surface of each succeeding swatch at 3-minute intervals. The upper chamber of each test cell was sealed. A 1.0 L/min flow of temperature- and humidity-controlled fresh air was supplied to the lower test cell chamber beneath each swatch.

During the 24-hr test period, gas samples were taken on a sequential basis from the airstream beneath each swatch by a laboratory MINICAMSTM with stream selection system (a miniaturized gas chromatograph with flame photometric detector and sampling system (OI Analytical, CMS Field Products Group, Birmingham, AL)). Gas sampling by the MINICAMSTM began for the first swatch approximately 3 minutes following agent application. Subsequent 3-minute cycles of the MINICAMSTM were composed of 2 minutes of desorption of collected agent vapor from the pre-concentrator tube (PCT) onto the column followed by 1 minute of gas sampling (collection of agent vapor in the PCT). Sampling was sequential through the six glove material swatches, the silicone swatch³, and three clean air gas samples (taken from the test cabinet to purge the MINICAMSTM and sampling line). The six glove material swatches, the silicone swatch, and three clean air gas samples were all sampled for the first time within the first 30 minutes of the test. Then the sampling sequence began anew.

The MINICAMSTM first determined the amount of agent vapor (ng) in each gas sample. Using this result, the amount of agent vapor per unit area (ng/cm²) present in the airstream that passed beneath the swatch over the time from the previous gas sample to the current gas sample was determined by the MINICAMSTM permeation software. The calculations assumed that the permeation rate is constant such that the mass permeating increases linearly over the 30-min interval. The permeation for each time interval was the average of the permeation rates (flux, ng/cm²/min) for the current and the previous gas samples multiplied by 30 min. This amount of agent vapor per unit area was presumed to be the amount of agent vapor

³ Originally, it was intended to use silicone swatches as references or controls, but it was soon found that permeation through the silicone varies too widely for it to be used for that purpose. Silicone swatches were used anyway, because they serve as a reliable source of agent vapor to assure the tester that the MINICAMS(r) is responding properly during tests when little or no agent permeates the actual test swatches.

per unit area that had permeated the swatch over that time interval. The cumulative mass of agent permeating the swatch per unit area at any elapsed time during the 24-hr test was defined as M_f . It was based on the mass permeated in the time interval over the effective swatch area, which was the opening in the permeation cell (10 cm^2), and was determined by the MINICAMSTM permeation software. Over the 24-hr test period, a series of M_f values was calculated for each swatch.

3.2.2 Liquid Challenge/Vapor Permeation Testing Analysis

Each glove had M_f data for 6 swatches for each of the two agents over the 24-hr test period. The M_f data were taken for each of the three swatches from one sampling area tested with one of the agents. For this report, the average (of three swatches) cumulative permeation (M_f) was calculated. This average was then presented, at each of the reported elapsed times, as representative of the glove's permeation resistance at that sampling area. The reported elapsed time for each sampling area was the average of the elapsed times for the three swatches.

To estimate M_f at each elapsed time for a glove, the simplifying assumption was that the exposure was uniform over the entire glove, and that the glove permeated in a way that is representative of the two sampled sites. This permitted the determination of an average M_f at each average elapsed time. The average elapsed time was the sum of the reported elapsed times for both sampling areas divided by two. The palm and cuff surface areas of the gloves were assumed to be equal. The average M_f at any average elapsed time was calculated using the following equation:

$$\text{Average } M_f = [(\text{palm material } M_f) + (\text{cuff material } M_f)]/2 \quad \textbf{Equation 1}$$

3.2.3 Relationship Between Liquid Challenge/Vapor Permeation Test Results and Skin Exposure

The permeation test was designed to distinguish among material swatches according to their permeation resistance to chemical agents. It was not intended to specifically replicate threat scenarios that may be encountered in actual use. As previously reported by Belmonte⁴, it was instructive to estimate the agent dosage ($C_{it_{skin}}$) that would result from such a standard agent challenge as a relative indication of possible physiological effects. This was done by converting the average M_f values to equivalent agent dosages. This relationship was developed by Fedele (written communication, Dr. P. Fedele, R&T Directorate, ERDEC, July 1997) and was reported by Belmonte⁴. For air-impermeable glove materials, the only mechanism for removal of agent vapor that permeates the barrier was assumed to be its permeation through the skin, so the equation is:

$$\text{Agent Dosage (mg - min/m}^3\text{)} = \frac{M_f \text{ (ng/cm}^2\text{)}}{\text{Permeability of skin to agent vapor (cm/min)}} \quad \textbf{Equation 2}$$

where skin permeability is 2 cm/min for HD and 0.1 cm/min for GB. The agent dosage was then compared to doses that are known to cause certain levels of toxicity. It was assumed that skin permeabilities of HD and GB are roughly constant over the entire body.

3.2.4 Evaluation Criteria for Liquid Challenge/Vapor Permeation Test Results

When analyzing the test results, it was useful to determine whether the data indicate that the chemical protective glove provides percutaneous protection over some period of time. Mustard vapor can produce erythema (reddening of the skin) at dosages of approximately

⁴ Test Results of Level A Suits to Challenge by Chemical and Biological Warfare Agents and Simulants: Summary Report. U. S. Army Edgewood Research Development and Engineering Center, MD. August 1998, UNCLASSIFIED Report (AD A353013).

1039 mg-min/m³ on the backs of the hands. It can produce vesication (skin burns and blisters) at 2078 mg-min/m³ on the backs of the hands. It was assumed that the hands were protected by the test gloves and challenged uniformly by the liquid dose used on the swatches. Using the threshold skin reddening dosage, and the skin permeability for mustard and substituting values in Equation 2, we obtained the HD threshold M_f value

$$\text{Threshold } M_f = 2 \times 1039 = 2078 \text{ ng/cm}^2 \quad \text{Equation 3}$$

Sarin vapor can produce incapacitation at percutaneous dosages of approximately 8000 mg-min/m³ and can cause lethality at dosages of 15000 mg-min/m³ where exposed persons are healthy, young, fit, and well-nourished males of approximately 70-kg mass. People who are smaller, less fit, etc., may exhibit adverse effects at lower doses ($C_{it_{skin}}$). Unlike mustard, Sarin acts systemically: the body reacts to the total amount of Sarin absorbed by the body. For this analysis it was assumed that the gloves were incorporated into a full ensemble protecting the entire body, but that only the gloves were challenged by liquid agent. The amount of Sarin agent per unit area (average M_f) necessary to permeate glove material covering the hands and forearms and produce a predetermined systemic effect was estimated by using the whole body dosage threshold of incapacitation (8000 mg-min/m³), the skin permeability to Sarin agent (0.1 cm/min) from Equation 2 and 8.41% as the fractional area (proportion of the total body area represented by the hands and forearms in the BRHA model⁵). The relationship is:

$$\text{Threshold } M_f = (\text{Threshold dose} \times \text{skin permeability}) / (\text{fractional area}) \quad \text{Equation 4}$$

⁵ Fedele, Dr. Paul D., Nelson, Douglas, C., *A Method of Assessing Full Individual Protective System Performance Against Cutaneous Effects of Aerosol and Vapor Exposures*, U.S. Army Edgewood Research, Development and Engineering Center, Aberdeen Proving Ground, Maryland, October, 1995; Section 1-3 "Body Region Hazard Analysis Process" included in the report for the JSLIST Program: Cronin, Tracy D., *Final Report for the Development of the Man-In-Simulant Test (MIST) Methodology for Evaluation of Chemical/Biological (CB) Protective Garments*, TECOM Project No. 8-EI-825-ABO-004, U.S. Army Dugway Proving Ground, Dugway, Utah, April 1996.

Substituting,

$$M_f = (8000 \times 0.1) / (0.0841) = 9,512 \text{ ng/cm}^2 \quad \text{Equation 5}$$

This value was used in the graphs of average M_f versus time and was summarized in Table 1. The breakthrough time was the time at which the average M_f reached the GB threshold value for M_f .

Table 1. Agent Breakthrough Criteria

Agent	Threshold Dosage (mg-min/m ³)	Physiological Effect	Skin Permeability, P _s (cm/min)	Threshold, M _f (ng/cm ²)
HD	1,039	Erythema	2	2,078
HD	2,078	Vesication	2	4,156
GB	8,000	Incapacitation	0.1	9,512
GB	15,000	Lethality	0.1	17,836

4. RESULTS AND DISCUSSION

The breakthrough times and average swatch thicknesses from all the glove designs were collected and presented in Table 2.

Table 2. Swatch Test Results for Gloves

Item	Average Swatch Thickness, mils	Breakthrough time, minutes	
		HD	GB
N-Dex Disposable Nitrile, B6005FPL	4	53	51
North Butyl, L112A0902	20	>1440	>1440
North Viton, L112A0661	16	>1440	132
North Silver Shield, L112A0647	4	>1440	>1440

For the North Butyl and North Viton glove designs, it was observed that the cuff swatches were noticeably thinner than the palm swatches. The North Butyl cuff swatches averaged approximately 16 mils versus approximately 24 mils for the palm swatches. The North

Viton cuff swatches averaged approximately 12 mils versus approximately 20 mils for the palm swatches. This fact may be a possible explanation for the increased GB vapor permeation noted for the cuff swatches of the North Viton glove design.

5. CONCLUSIONS.

The test data revealed that the chemical protective glove designs tested can protect the wearers from liquid CW agents. Breakthrough time should not be interpreted as the time that a glove can be safely worn, either for HD or GB. Breakthrough times should only be used to compare glove materials.

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ACRONYMS and ABBREVIATIONS

Ct	Vapor exposure, product of vapor concentration (mg/m ³) and time (minutes)
C _{It_{skin}}	Vapor exposure to skin
cm ²	Square centimeters
°F	Temperature in degrees Fahrenheit
delta p	Differential pressure
DoD	Department of Defense
ECBC	U.S. Army Edgewood Chemical Biological Center
ERDEC	U.S. Army Edgewood Research, Development and Engineering Center
g	Gram
GB	Sarin, Isopropylmethylphosphonofluoridate
HD	Sulfur Mustard; 2,2'-Dichlorodiethylsulfide
L	Liter
M _f	Cumulative mass permeation through the material
m ²	Square meters
m ³	Cubic meters
mg	Milligram
μL	Microliter
ng	Nanogram
NBC	Nuclear, Biological and Chemical
PCT	Pre-concentrator tube
PPE	Personal Protective Equipment
P _s	Skin permeability
RH	Relative Humidity
TOP	Test Operations Procedure

Appendix A
Gloves Chosen for Testing

Table A- 1 Gloves Tested

Model	Manufacturer	Address
N-Dex Disposable Nitrile, B6005FPL	Best Company	Baltimore, MD
North Butyl, L112A0902	North Safety Products	Charleston, SC
North Viton, L112A0661	North Safety Products	Charleston, SC
North Silver Shield, L112A0647	North Safety Products	Charleston, SC

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Appendix B

Modified Static Diffusion Test Procedure

MODIFIED STATIC DIFFUSION TEST

This test procedure was adapted from Test Operations Procedure (TOP) 8-2-501, Permeation and Penetration of Air-Permeable, Semipermeable and Impermeable Materials with Chemical Agents or Simulants (Swatch Testing). U.S. Army Dugway Proving Ground, UT. 3 March 1997, UNCLASSIFIED Report (AD A322329).

The following procedure was used:

1. Upon receipt of the gloves, all available information concerning the gloves will be recorded; date of manufacture, lot number, serial number, materials of construction, etc.

2. From each pair of gloves, one each 1 and 15/16 in diameter material swatch will be taken from the cuff area for HD and one like-sized material swatch will be taken from the cuff area for GB. From the same pair of gloves, one each 1 and 15/16 in diameter material swatch will be taken from the palm area for HD and one like-sized material swatch will be taken from the palm area for GB. Swatches will be taken from at least 3 pairs of gloves (a minimum of 6 HD swatches and 6 GB swatches will be tested) for each glove model/style. Thickness measurements will be taken and recorded for each swatch. Each swatch will be placed in an airtight bag and given a unique serial number, which will be placed on the bag. A list of serial numbers will be kept with the swatches.

3. The environmental chamber will be controlled at a temperature of 90 +/- 2 °F (32.2 +/- 1 °C) and the maximum achievable relative humidity without occurrence of condensation (60% +/- 10% RH). The temperature and RH readings will be checked weekly with a calibrated meter. The test cell air will

be drawn from the chamber air. [TOP 8-2-501 specifies that a system control and data acquisition system will be used but this system was not used due to budget constraints.] The temperature and RH will be recorded in a computer file. Flow rates will be manually recorded. [TOP 8-2-501 specifies that differential pressure monitoring will be done but differential pressure gages were not used due to budget constraints.]

4. The TOP test cell will be used. When assembling, the cell lugs will be tightened by hand to finger tight. The flow rate beneath each swatch will be 1 L/min, which will be controlled by a linear mass flow controller. The flows will be checked with a calibrated test meter weekly. Each test cell will be checked for leaks after assembly by connecting it to the vacuum source and checking that the inlet flow is the same as the outlet flow on the mass flow controller (cell lugs will be retightened if flows don't match).

5. The swatches will be preconditioned overnight in the environmental chamber. Eighty-mil silicone will be used as an indicator swatch to verify that the MINICAMS can detect agent vapor permeation (one silicone swatch per 6 glove swatches). [TOP 8-2-501 specifies that positive control and negative control swatches will be used but they were not used due to budgetary and schedule limitations.]

6. Agents GB and HD will be used. The contamination density will be 10 g/m² (eight 1 µL HD droplets or ten 1 µL GB droplets). The agent will be applied using the click/touch method with a Hamilton repeating dispenser. [TOP 8-2-501 specifies that a robotic agent application system will be used for agent application but this was not done due to budget constraints.]

7. Seven swatches will be tested at once. MINICAMS with stream selection system will monitor vapor permeation with a 3-minute cycle per swatch. There will be 3 blank sampling intervals following

the indicator swatch. Each swatch will be sampled once every 30 min. The MINICAMS will be standardized weekly.

8. The test length will be 24 hr.

9. The test cells and o-rings will be aerated between uses. No other cleaning method will be used.

10. The data to be reported are cumulative permeation (ng/cm^2) versus elapsed time from contamination (min) for each swatch. All recorded data will be placed in laboratory notebooks and a technical report will be drafted at the conclusion of this effort.

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Appendix C
N-Dex Disposable Nitrile



Figure C- 1 N-Dex Disposable Nitrile Glove

Table C- 1 N-Dex Disposable Nitrile Glove - Average HD Permeation

N-Dex Disposable Nitrile Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
5	1	14	1	10	1
35	1458	44	729	40	1093
65	3701	74	2941	70	3321
95	5306	104	5913	100	5610
125	6951	134	9569	130	8260
155	8553	164	12540	160	10547
185	10172	194	14115	190	12144
215	12590	224	17089	220	14839
245	15010	254	20752	250	17881
275	18132	284	24425	280	21279
305	22649	314	28854	310	25752
335	27290	344	33291	340	30291
365	31856	374	37741	370	34799
395	36115	404	42178	400	39147
425	40237	434	46596	430	43416
455	44765	464	51037	460	47901
485	49774	494	55504	490	52639
515	54807	524	59977	520	57392
545	59851	554	64460	550	62155
575	64863	584	69081	580	66972
605	69792	614	73715	610	71753
635	74642	644	78347	640	76494
665	79167	674	83097	670	81132
695	83388	704	87859	700	85624
725	87221	734	92420	730	89821
755	90927	764	96971	760	93949
782	94359				

Note: Sampling was ended prior to 24 hours to enable MINICAMS™ to return to baseline following high vapor permeation

Table C- 2 N-Dex Disposable Nitrile Glove - Average GB Permeation

N-Dex Disposable Nitrile Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
5	1	14	3	9	2
35	5275	44	5352	39	5314
65	15811	74	16029	69	15920
95	23988	104	25870	99	24929
125	28432	134	33861	129	31147
155	30935	164	39945	159	35440
185	32638	194	44686	189	38662
215	33989	224	48728	219	41359
245	35127	254	52398	249	43763
275	36139	284	55877	279	46008
305	37059	314	59187	309	48123
335	37898	344	62327	339	50112
365	38686	374	65377	369	52032
395	39430	404	68273	399	53852
425	40143	434	71047	429	55595
455	40812	464	73725	459	57269
485	41449	494	76254	489	58851
515	42067	524	78712	519	60389
545	42649	554	81036	549	61842
575	43203	584	83223	579	63213
605	43730	614	85354	609	64542
635	44230	644	87336	639	65783
665	44704	674	89144	669	66924
695	45150	704	90866	699	68008
725	45585	734	92507	729	69046
755	45990	764	94048	759	70019

Note: Sampling was ended prior to 24 hours to enable MINICAMS™ to return to baseline following high vapor permeation.

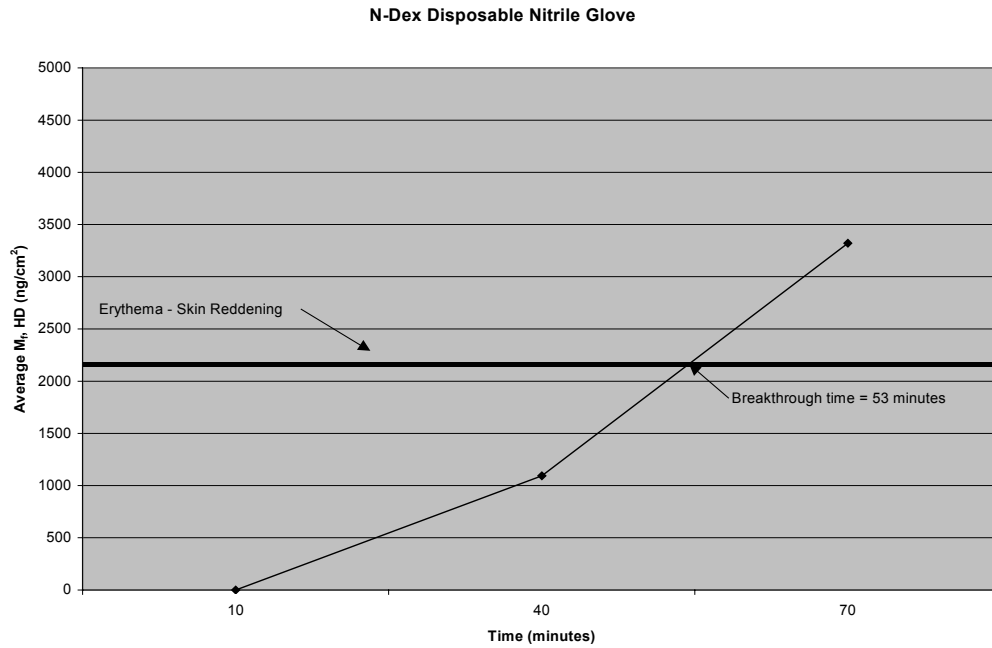


Figure C- 2 N-Dex Disposable Nitrile Glove - Average HD Cumulative Permeation

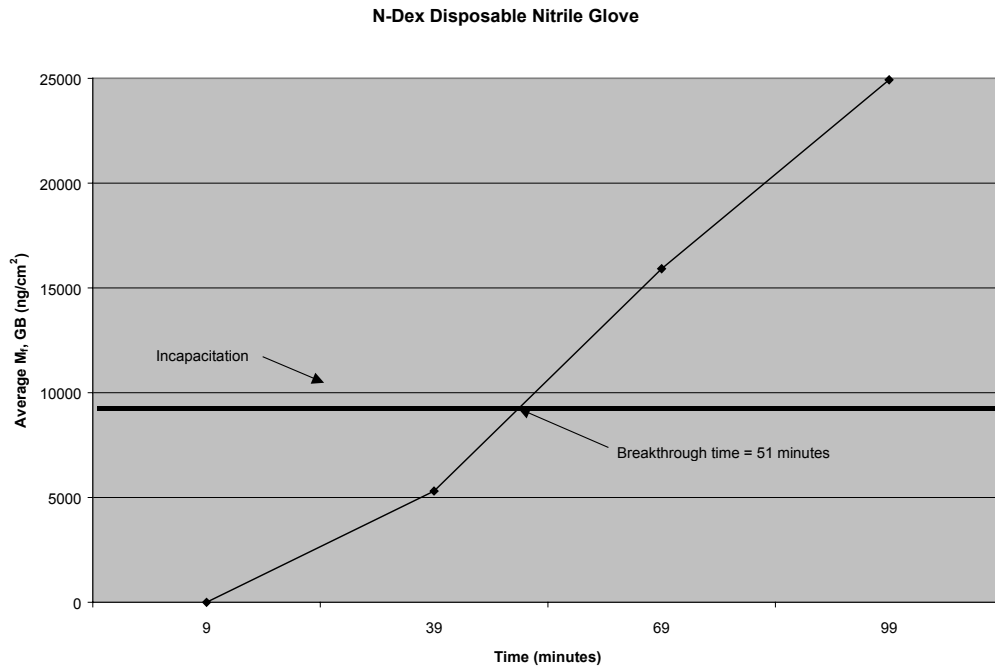


Figure C- 3 N-Dex Disposable Nitrile Glove - Average GB Cumulative Permeation

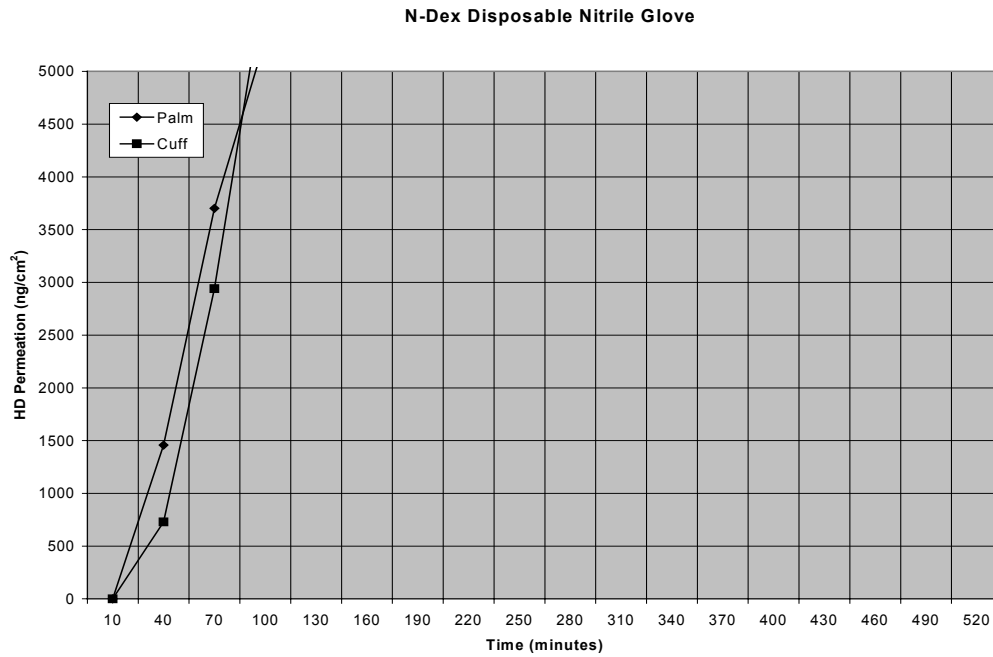


Figure C- 4 N-Dex Disposable Nitrile Glove: HD Cumulative Permeation by Sampling Area

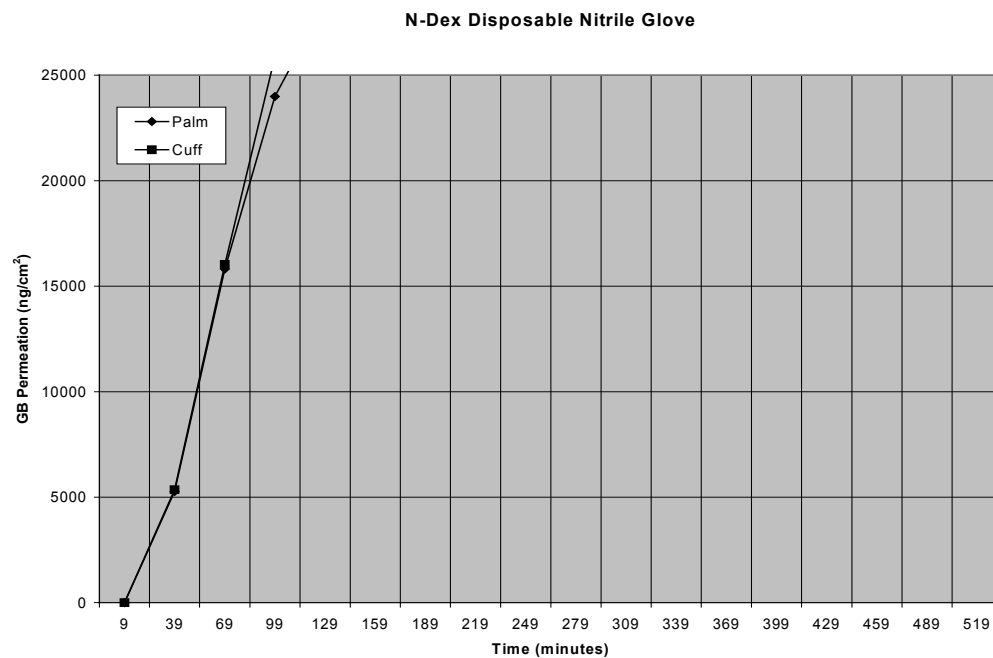


Figure C- 5 N-Dex Disposable Nitrile Glove: GB Cumulative Permeation by Sampling Area

Appendix D

North Butyl



Figure D- 1 North Butyl Glove

Table D- 1 North Butyl Glove - Average HD Permeation

North Butyl Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
4	0	14	0	9	0
34	0	44	0	39	0
64	1	74	0	69	0
94	1	104	1	99	1
124	1	134	1	129	1
154	1	164	1	159	1
184	1	194	1	189	1
214	3	224	1	219	2
244	5	254	1	249	3
274	8	284	1	279	5
304	13	314	3	309	8
334	19	344	5	339	12
364	26	374	7	369	17
394	37	404	11	399	24
424	51	434	16	429	34
454	68	464	21	459	44
484	85	494	27	489	56
514	103	524	32	519	67
544	120	554	37	549	78
574	137	584	43	579	90
604	153	614	48	609	100
634	168	644	53	639	110
664	183	674	58	669	121
694	198	704	63	699	131
724	213	734	68	729	140
754	227	764	72	759	150
784	241	794	77	789	159
815	254	825	82	820	168
845	266	855	86	850	176
876	277	886	90	881	184
906	288	916	94	911	191
937	299	947	98	942	198
967	310	978	102	972	206
995	316	1005	104	1000	210
1022	317	1032	105	1027	211
1050	318	1060	105	1055	211
1077	318	1087	105	1082	212
1105	319	1115	105	1110	212
1132	319	1142	105	1137	212
1160	320	1170	105	1165	213
1187	321	1197	105	1192	213
1215	321	1225	106	1220	214
1242	322	1252	106	1247	214
1270	323	1280	108	1275	215
1297	323	1307	109	1302	216
1324	324	1335	110	1330	217
1352	326	1362	112	1357	219
1379	327	1390	113	1384	220
1407	329	1417	115	1412	222
1434	330				

Table D- 2 North Butyl Glove - Average GB Permeation

North Butyl Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
4	0	13	0	8	0
34	7	43	7	38	7
64	16	73	18	68	17
94	19	103	24	98	22
124	21	133	27	128	24
154	23	163	29	158	26
184	25	193	31	188	28
214	27	223	33	218	30
244	28	253	34	248	31
274	30	283	35	278	32
304	31	313	36	308	34
334	32	343	37	338	34
364	34	373	37	368	35
394	35	403	37	398	36
424	36	433	37	428	36
454	37	463	37	458	37
484	38	493	37	488	37
514	39	523	37	518	38
544	40	553	37	548	38
574	41	583	37	578	39
604	41	613	37	608	39
634	41	643	37	638	39
664	41	673	37	668	39
694	41	703	37	698	39
724	41	733	37	728	39
754	41	763	37	758	39
784	41	793	37	788	39
814	41	823	37	818	39
844	41	853	37	848	39
874	41	883	37	878	39
904	41	913	37	908	39
934	41	943	37	938	39
964	41	973	37	968	39
994	41	1003	37	998	39
1024	41	1033	37	1028	39
1054	41	1063	37	1058	39
1084	41	1093	37	1088	39
1114	41	1123	37	1118	39
1144	41	1153	37	1148	39
1174	42	1183	37	1178	39
1204	42	1213	37	1208	40
1234	43	1243	37	1238	40
1264	44	1273	37	1268	40
1294	44	1303	37	1298	41
1324	44	1333	37	1328	41
1354	44	1363	37	1358	41
1384	45	1393	37	1388	41
1414	45	1423	37	1418	41

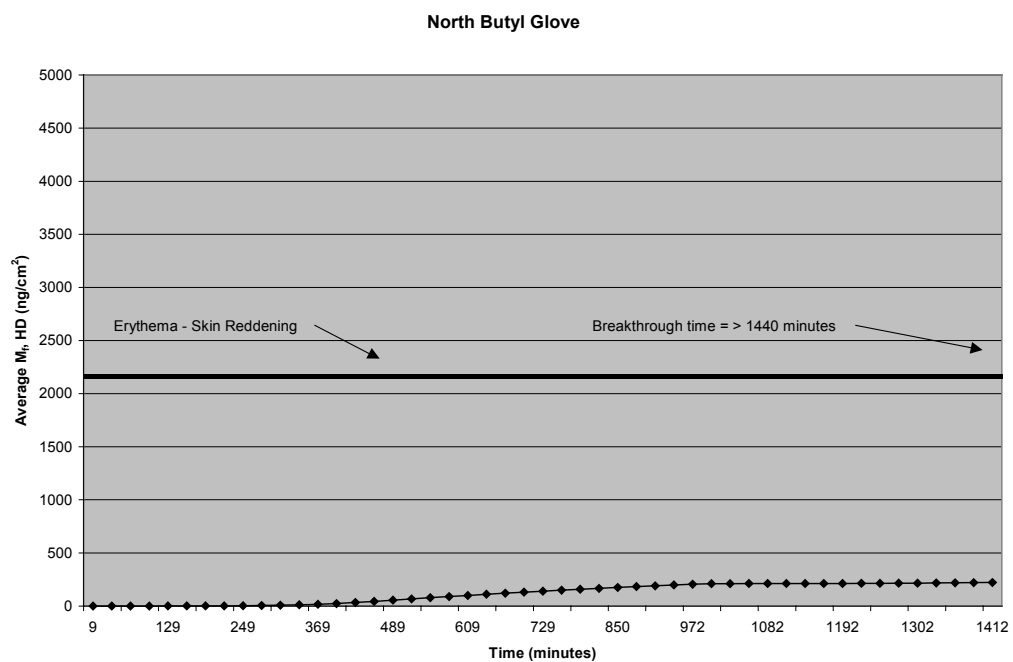


Figure D- 2. North Butyl Glove - Average HD Cumulative Permeation

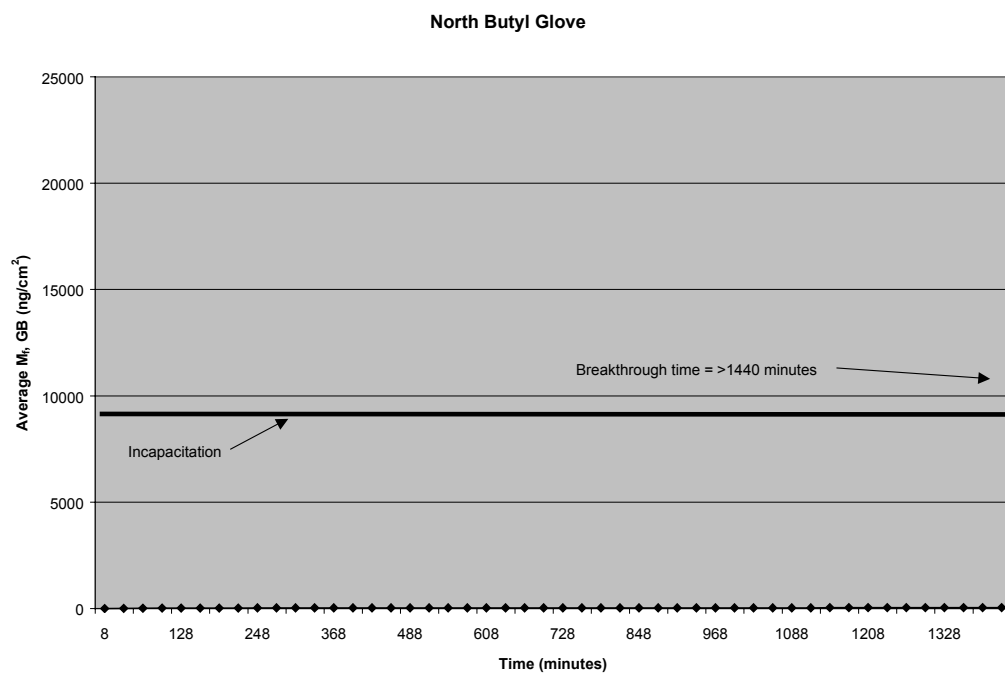


Figure D- 3 North Butyl Glove -Average GB Cumulative Permeation

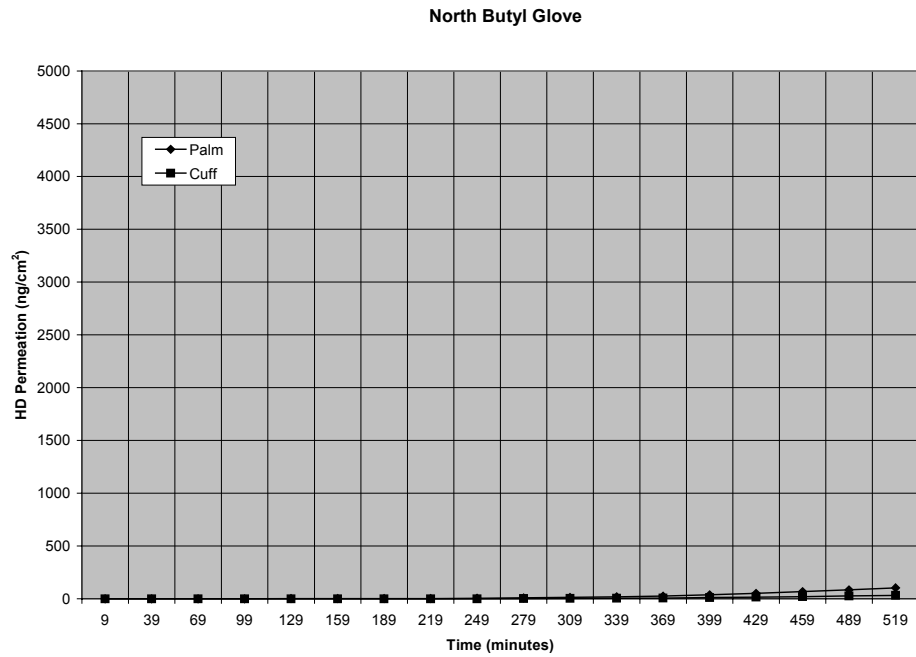


Figure D- 4 North Butyl Glove - HD Cumulative Permeation by Sampling Area

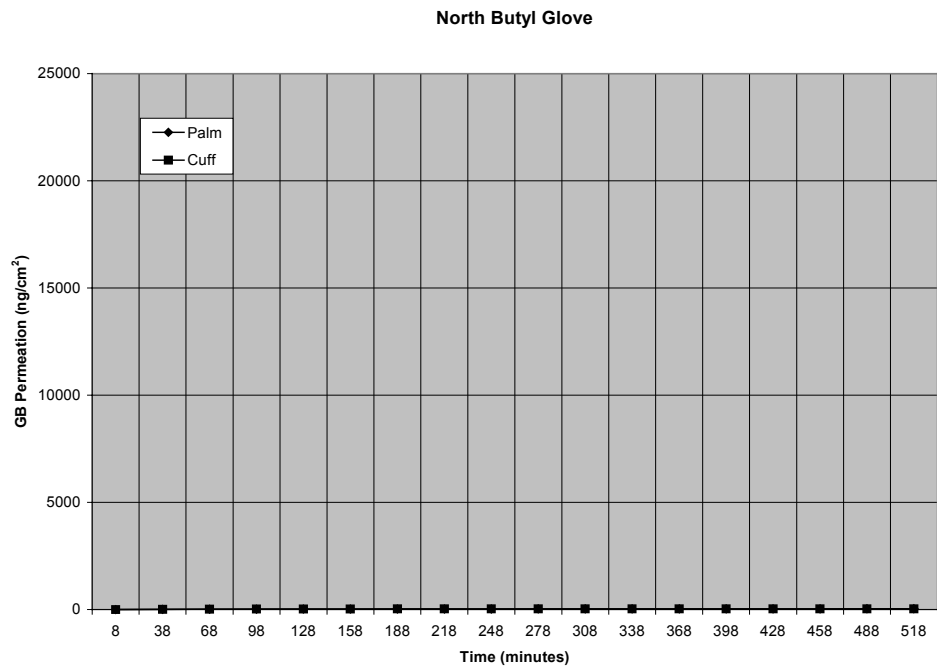


Figure D- 5 North Butyl Glove - GB Cumulative Permeation by Sampling Area

Appendix E

North Viton



Figure E- 1 North Viton Glove

Table E- 1 North Viton Glove - Average HD Permeation

North Viton Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
5	0	14	1	10	1
35	2	44	3	40	3
65	3	74	4	70	3
95	4	104	5	100	4
125	5	134	6	130	5
155	6	164	7	160	7
185	7	194	9	190	8
215	9	224	10	220	10
245	11	254	12	250	12
275	14	284	14	280	14
305	17	314	16	310	17
335	21	344	18	340	19
365	24	374	21	370	22
395	27	404	24	400	26
425	30	434	27	430	29
455	34	464	29	460	31
485	37	494	31	490	34
515	40	524	33	520	36
545	42	554	35	550	38
575	44	584	36	580	40
605	45	614	38	610	42
635	46	644	40	640	43
665	47	674	41	670	44
695	49	704	42	700	45
725	50	734	43	730	47
755	51	764	45	760	48
785	52	794	46	790	49
815	53	824	47	820	50
845	54	854	48	850	51
875	55	884	49	880	52
905	55	914	50	910	53
935	56	944	51	940	54
965	57	974	52	970	55
995	58	1004	53	1000	56
1025	59	1034	54	1030	57
1055	60	1064	55	1060	58
1085	61	1094	56	1090	58
1115	61	1124	57	1120	59
1145	62	1154	58	1150	60
1175	63	1184	59	1180	61
1205	64	1214	60	1210	62
1235	65	1244	61	1240	63
1265	66	1274	62	1270	64
1295	67	1304	64	1300	65
1325	67	1334	65	1330	66
1355	68	1364	66	1360	67
1385	69	1394	67	1390	68
1415	70	1424	68	1420	69

Table E- 2 North Viton Glove - Average GB Permeation

North Viton Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
6	1	15	4	10	2
36	7	45	17	40	12
66	12	75	78	70	45
96	16	105	6127	100	3071
126	63	135	18295	130	9179
156	164	165	30226	160	15195
186	278	195	41395	190	20836
216	385	225	51704	220	26044
246	480	255	60939	250	30709
276	564	285	69089	280	34826
306	640	315	76296	310	38468
336	711	345	82740	340	41726
366	781	375	88554	370	44667
396	853	405	93859	400	47356
426	931				
453	1002				
477	1059				
501	1113				
525	1166				
549	1218				
570	1261				
591	1301				
612	1339				
633	1377				
654	1413				
675	1449				
696	1484				
717	1518				
738	1551				
759	1585				
780	1618				
801	1652				
822	1685				
843	1719				
864	1753				
885	1789				
906	1825				
927	1863				
948	1901				
969	1941				
990	1983				
1011	2025				
1032	2070				
1053	2117				
1074	2164				
1095	2213				
1116	2264				
1137	2317				
1158	2373				
1179	2429				
1200	2487				
1221	2547				
1242	2609				

North Viton Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
1263	2672				
1284	2736				

Note: Sampling of cuff swatches was ended prior to 24 hours to enable MINICAMS™ to return to baseline following high vapor permeation.

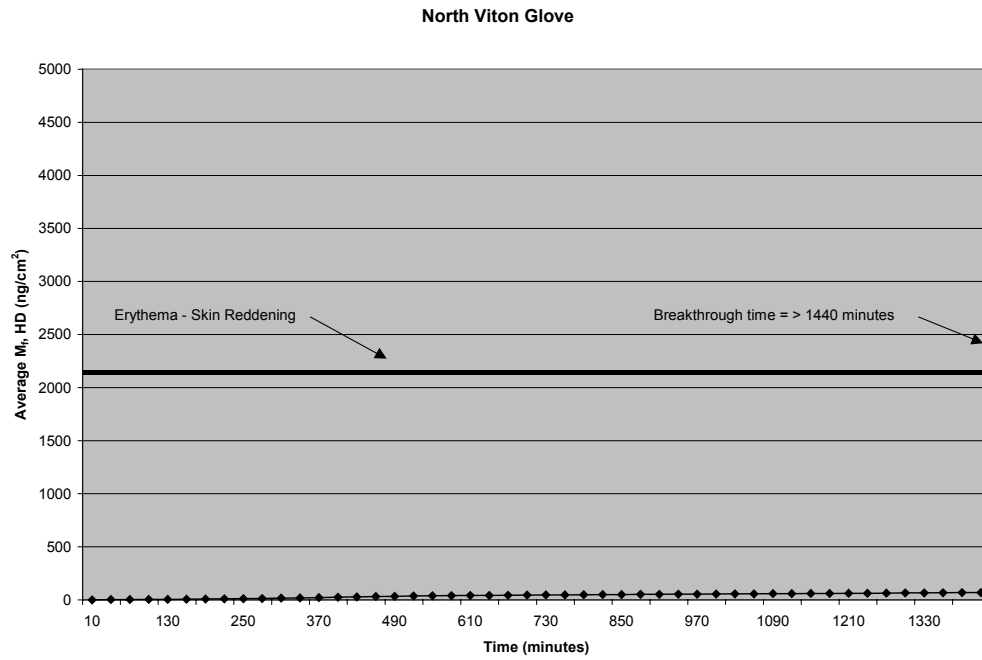


Figure E- 2 North Viton Glove - Average HD Cumulative Permeation

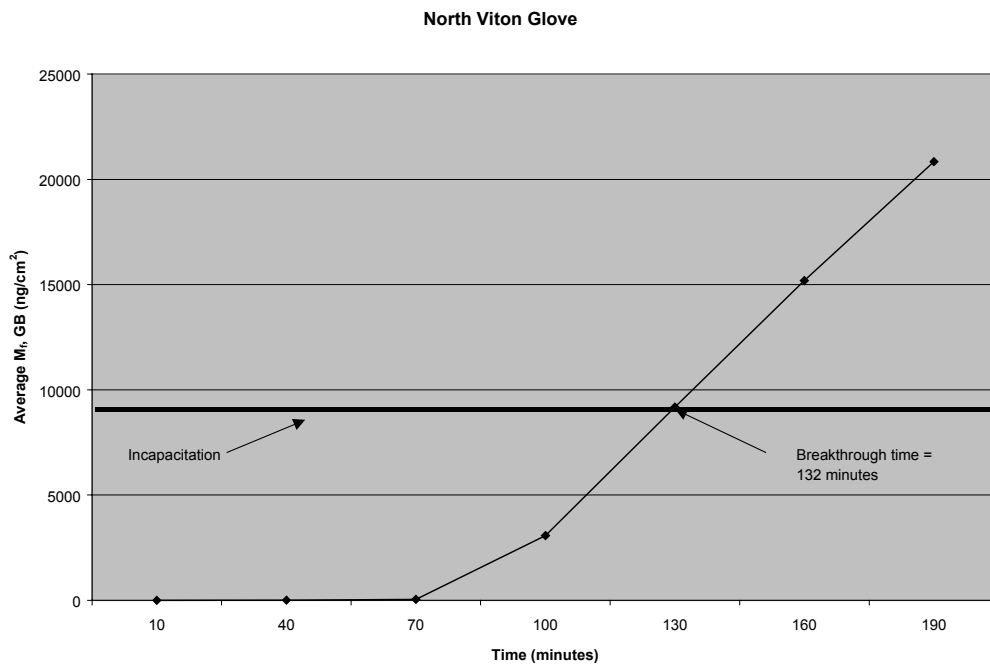


Figure E- 3 North Viton Glove - Average GB Cumulative Permeation

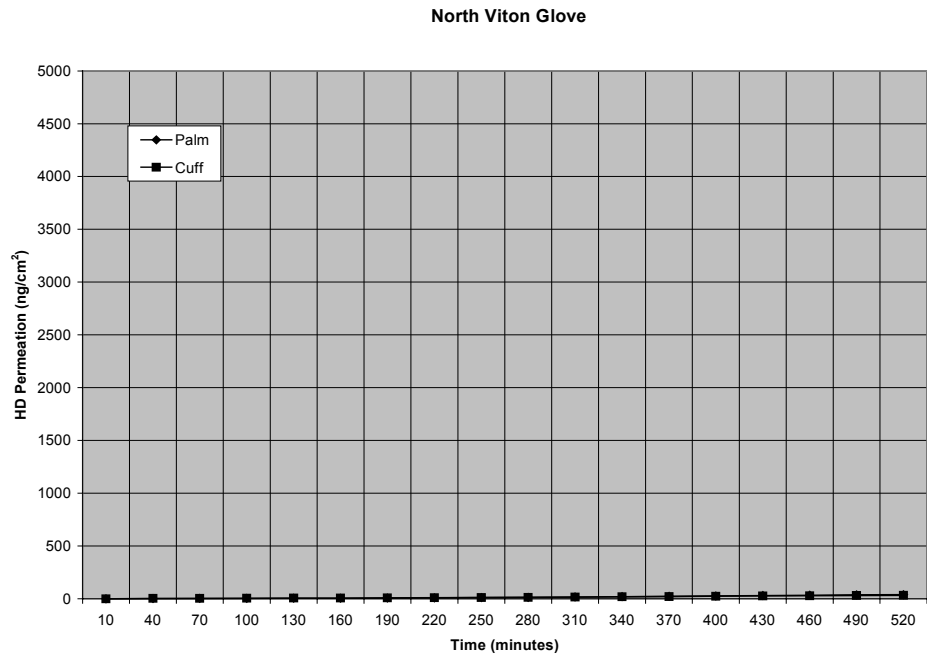


Figure E- 4 North Viton Glove: HD Cumulative Permeation By Sampling Area

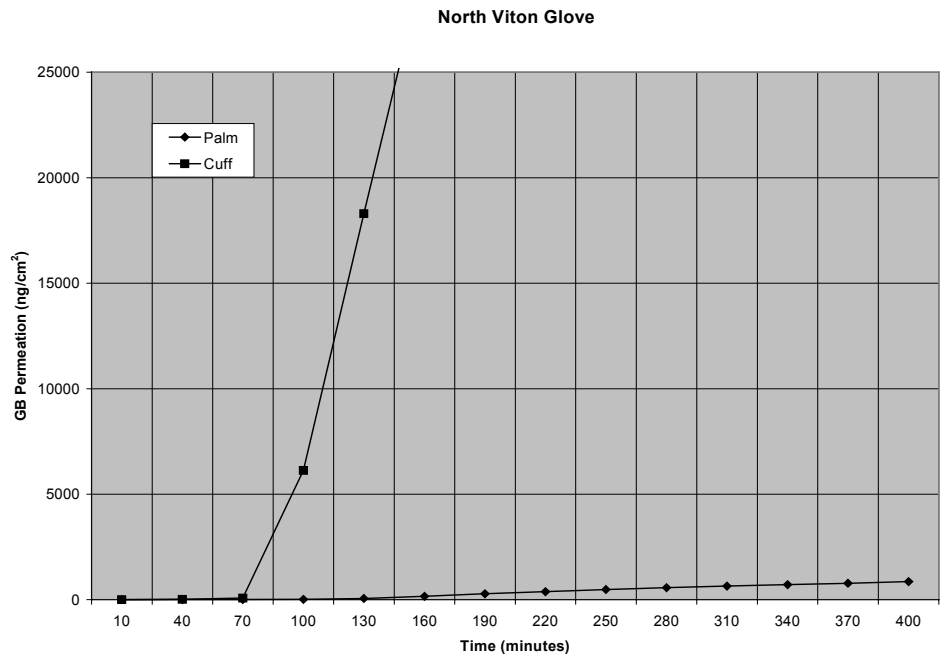


Figure E- 5 North Viton Glove: GB Cumulative Permeation By Sampling Area

Blank

Appendix F
North Silver Shield



Figure F- 1 North Silver Shield Glove

Table F- 1 North Silver Shield Glove - Average HD Permeation

North Silver Shield Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
4	0	13	0	8	0
34	0	43	1	38	1
64	0	73	2	68	1
94	0	103	2	98	1
124	0	133	2	128	1
154	0	163	2	158	1
184	0	193	2	188	1
214	1	223	2	218	1
244	2	253	2	248	2
274	3	283	2	278	3
304	6	313	2	308	4
334	9	343	4	338	6
364	12	373	6	368	9
394	16	403	7	398	12
424	20	433	9	428	14
454	23	463	11	458	17
484	27	493	13	488	20
514	31	523	15	518	23
544	35	553	17	548	26
574	38	583	18	578	28
604	42	613	20	608	31
634	46	643	22	638	34
664	50	673	25	668	37
694	54	703	27	698	40
724	57	733	29	728	43
754	61	763	31	758	46
784	64	793	33	788	48
814	67	823	35	818	51
844	70	853	37	848	53
874	73	883	38	878	56
904	76	913	40	908	58
934	79	943	41	938	60
964	82	973	43	968	62
994	84	1003	44	998	64
1024	87	1033	45	1028	66
1054	89	1063	45	1058	67
1084	92	1093	46	1088	69
1114	94	1123	46	1118	70
1144	97	1153	47	1148	72
1174	99	1183	47	1178	73
1204	102	1213	48	1208	75
1234	104	1243	49	1238	76
1264	107	1273	50	1268	78
1294	109	1303	50	1298	80
1324	112	1333	51	1328	81
1354	114	1363	52	1358	83
1384	117	1393	52	1388	84
1414	119	1423	53	1418	86

Table F- 2 North Silver Shield Glove – Average GB Permeation

North Silver Shield Glove					
Time (minutes)	M _f , Palm (ng/cm ²)	Time (minutes)	M _f , Cuff (ng/cm ²)	Average Time (minutes)	Average M _f (ng/cm ²)
4	1	13	8	8	4
34	13	43	46	38	29
64	23	73	82	68	53
94	32	103	112	98	72
124	40	133	139	128	90
154	48	163	163	158	106
184	55	193	186	188	120
214	62	223	207	218	135
244	69	253	227	248	148
274	76	283	246	278	161
304	83	313	264	308	174
334	89	343	283	338	186
364	96	373	302	368	199
394	102	403	320	398	211
424	108	433	336	428	222
454	114	463	350	458	232
484	119	493	364	488	241
514	123	523	377	518	250
544	128	553	389	548	259
574	133	583	402	578	267
604	137	613	413	608	275
634	141	643	425	638	283
664	146	673	436	668	291
694	150	703	446	698	298
724	154	733	457	728	305
754	158	763	467	758	312
784	162	793	477	788	319
814	166	823	487	818	326
844	169	853	496	848	333
874	173	883	505	878	339
904	177	913	514	908	345
934	180	943	523	938	352
964	184	973	531	968	358
994	188	1003	540	998	364
1024	191	1033	548	1028	370
1054	195	1063	557	1058	376
1084	198	1093	565	1088	381
1114	202	1123	573	1118	387
1144	205	1153	580	1148	393
1174	208	1183	588	1178	398
1204	211	1213	595	1208	403
1234	215	1243	603	1238	409
1264	218	1273	611	1268	415
1294	222	1303	619	1298	421
1324	225	1333	628	1328	426
1354	229	1363	636	1358	432
1384	232	1393	643	1388	438
1414	236	1423	650	1418	443

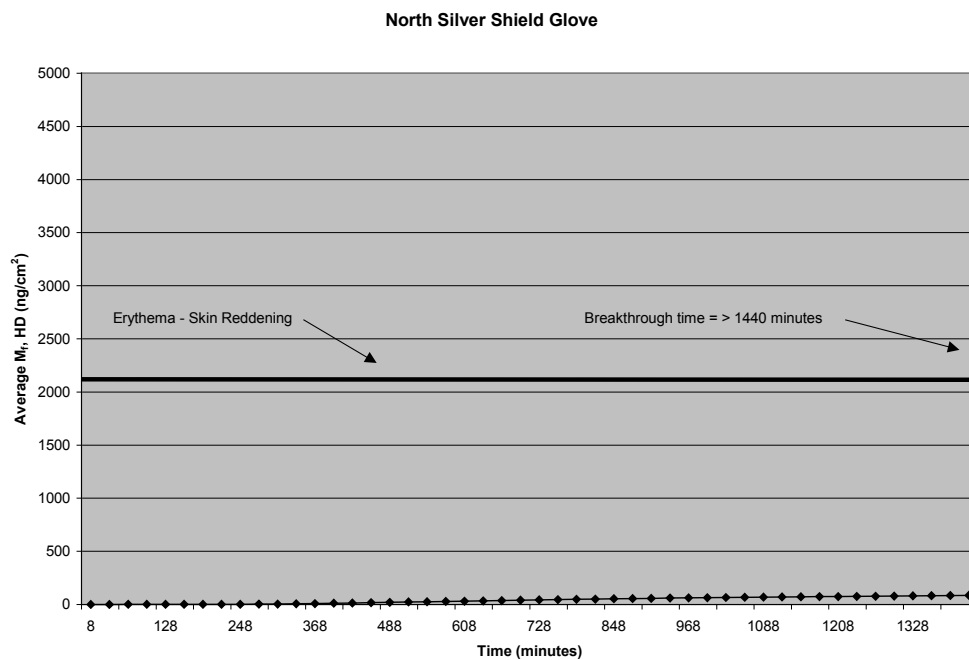


Figure F- 2 North Silver Shield Glove - Average HD Cumulative Permeation

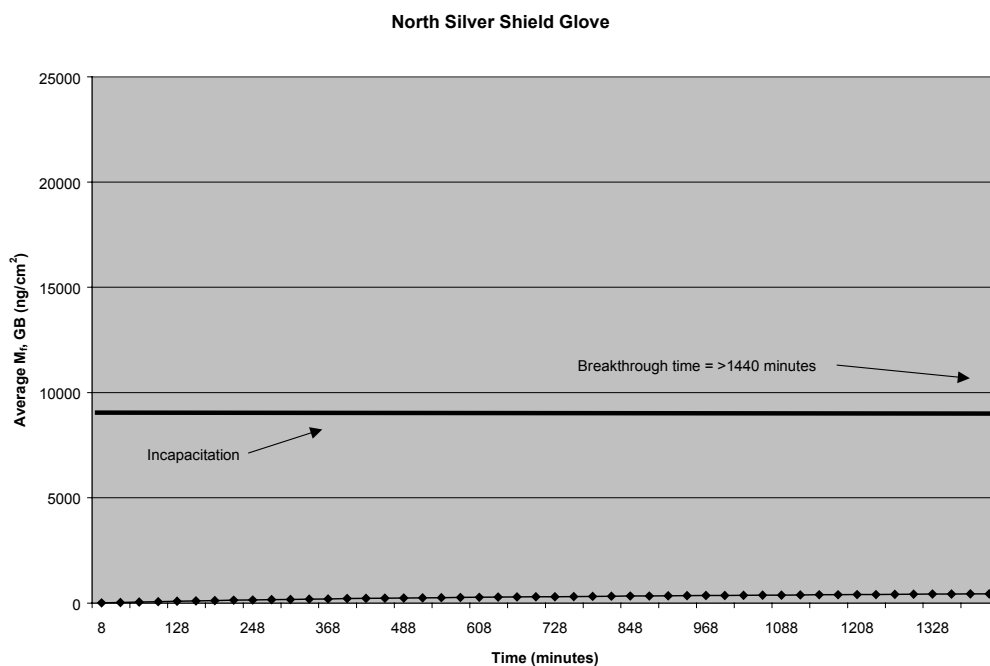


Figure F- 3 North Silver Shield Glove - Average GB Cumulative Permeation

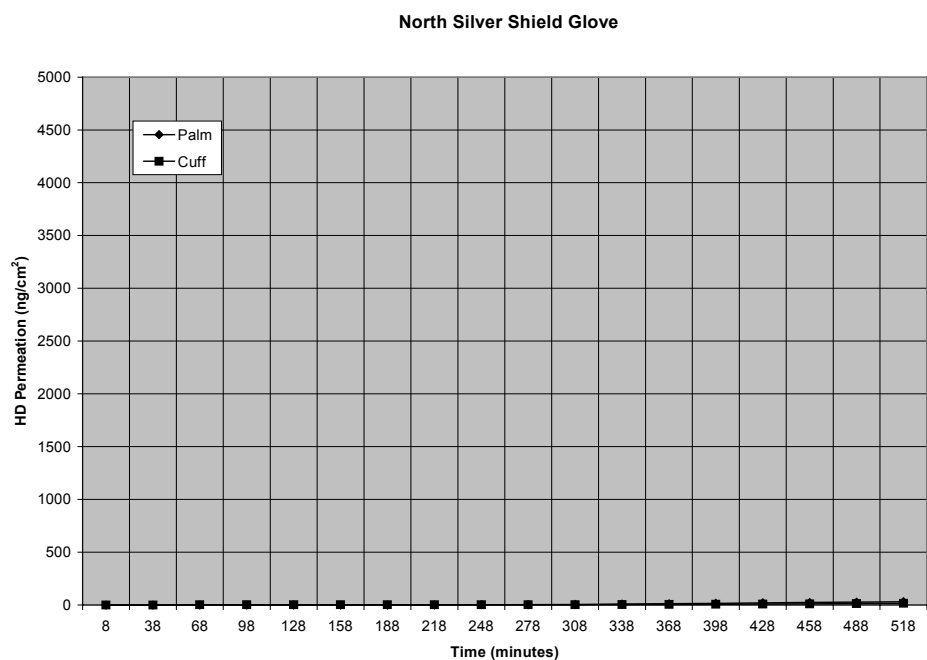


Figure F- 4 North Silver Shield Glove - HD Cumulative Permeation by Sampling Area

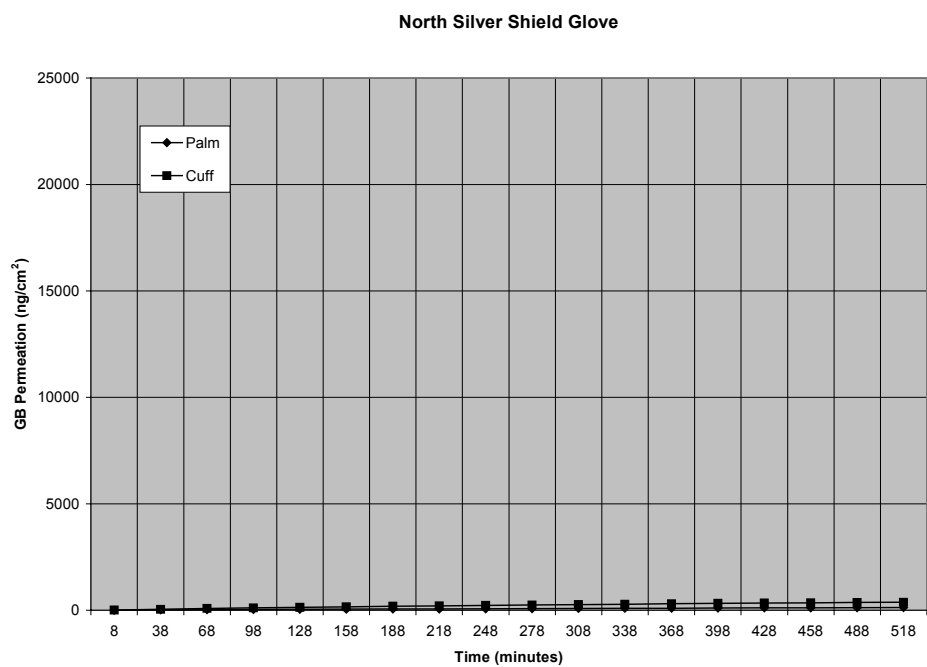


Figure F- 5 North Silver Shield Glove - GB Cumulative Permeation by Sampling Area

Appendix G

Overall Test Results

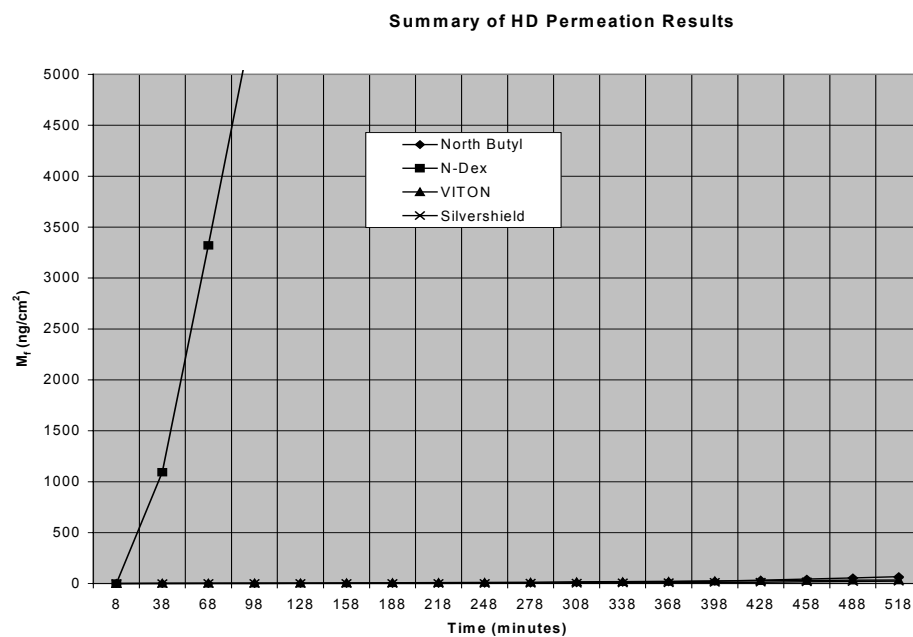


Figure G- 1 Average HD Cumulative Permeation

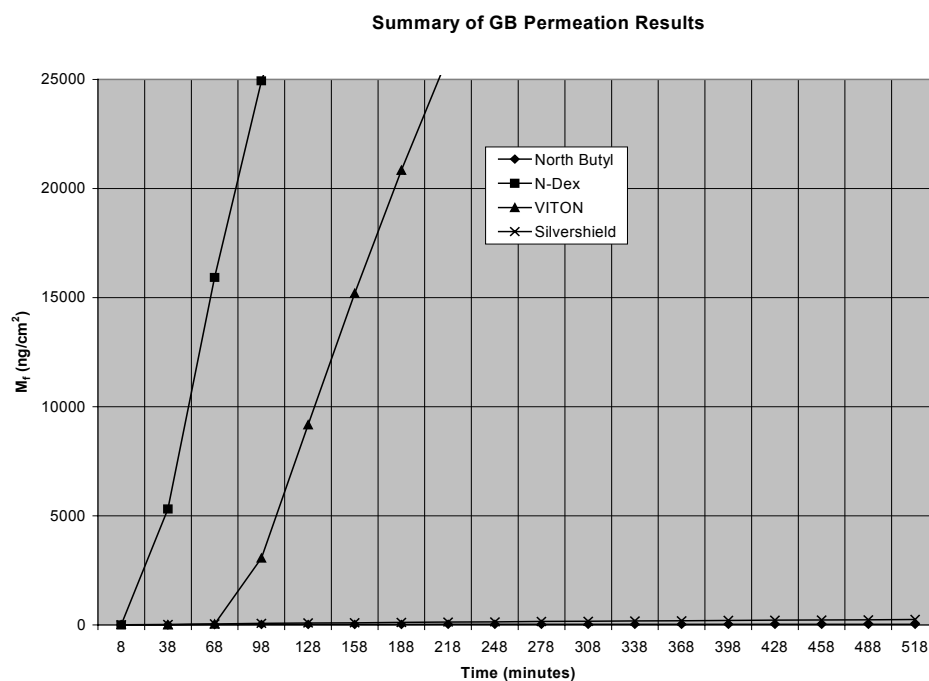


Figure G- 2 Average GB Cumulative Permeation

